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Modified Coverage Hole Detection Algorithm for Distributed WSNs

K. Lakshmi Joshitha[1] and Dr.S.Jayashri[2]
[1] Research Scholar, Anna University, Chennai, India
Email: lakshmijoshitha@yahoo.com
[2]Director, Adhiparasakthi Engineering College, Chennai, India
Email: jayaravi2010@gmail.com

***Abstract*— Wireless sensor networks (WSNs) are spatially distributed sensors that find wide applications in various fields such as environmental control, Medicine and Health care, Military surveillance etc. The sensing and communication within the network should be effective for such applications. Holes are the voids created in the network when accidental death of nodes is caused due to technical or improper coverage. The detection of the holes becomes essential after the random deployment. The main objective of the work is to detect the coverage holes using computational geometry approach which uses co-ordinates of the sensors and to implement it in the hardware. The communication range of a node is considered to be equal to its sensing range. The protocol is designed for irregular domain which is a real time scenario and takes the help of two-hop neighbors' of a node to detect the hole around it. The proposed system also allows only few nodes to initiate the detection algorithm so that the energy and time is conserved.**

***Index Terms*— Coverage holes, computational geometry approach, communication range, sensing range, two-hop neighbors.**

I. Introduction

In cases like volcanic regions, forests areas or monitoring physical conditions of a region, wireless sensor networks plays an important role which collects the physical parameters and converts it into electrical parameters with the help of sensors. In wireless sensor networks (WSNs), sensors are distributed randomly to form the network dynamically without help of any infrastructure. The distributions of sensors are not usually uniform due to random aerial deployment, presence of obstructions, and node failures caused by power depletion. In the post deployment scenarios, nodes deployed over certain region may be destroyed due to intrusion, explosion or environmental factors like heat, vibration, and failure of electronic components or software bugs. In another scenario, power sources of the nodes may lead death of the nodes, thereby affecting the coverage of the original network giving rise to holes.

Holes are 'communication voids' as they act as an obstacle for communication. Hence, holes can hardly be avoided in wireless sensor networks. On the other hand, holes are important indicators of the general health of a sensor network. The presence of holes in the underlying geometric environment could have important consequences on the performance of the sensor network. Number of holes is inversely proportional to efficient communication.

II. Related Work

In wireless sensor networks, determination of hole is of prime importance and several authors have proposed different types of algorithms for different networks like static ,hybrid and mobile sensor networks[1].The discussion in [2] includes the detection of coverage holes based on the Voronoi graph, and development of algorithms to make the sensor networks as uniform as possible. The basic triangulation method of sensor networking of 2D and 3D surface is dealt in [3]. A grid-based system model [4] is proposed to detect the coverage hole. A two phase sensor relocation is also proposed.. The hole detection methods in [5] proposes optimal polynomial time worst and average case algorithm for coverage calculation. Reference [6] deals with the method to identify one, two or a larger single coverage hole and suggests the mobility scheme to provide coverage. Localized voronoi polygon and neighbor embracing polygon method is used for identifying hole in [7].Deterministic method for boundary node detection based on localized Voronoi polygons is proposed in [8]. The algorithm uses only the one-hop information with fewer computations.

The proposed algorithm MHDA (Modified Hole Detection Algorithm) is localized one and requires one-hop neighbors' information to detect the holes. A distributed so called path density (PS) algorithm [9] is developed to detect the coverage holes in WSNs. It uses the path density to detect the holes by the neighbors of a dead sensor. The PS algorithm can detect coverage holes remotely, but requires more time and power consumption for detecting holes in practice. Reference [10,11] gives details about the statistical, topological and the geometrical approaches of the sensor network and gives the Hop based hole detection process.

A k-coverage verification scheme for a target field is proposed, which requires a predefined value of k. According to this scheme, each node has only localized distance information of the distance between adjacent nodes in its vicinity and their sensing radius. Besides, an upper-bounded sensing radius and lower-bounded transmission radius of each node is considered. As per the proposed scheme, this could be achieved by configuring the nodes before placing them or by walking along the target field boundary with a handheld device. However, it is quite difficult due to random

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deployment nature of the sensors and geographical condition of the monitoring region.

III. Proposed System

The proposed system has few nodes initiating the algorithm for specific region while the existing system includes all the nodes in the network to initiate the hole detection algorithm. Clustering of the given nodes is done by choosing the cluster size of 16.Here the clusters are of overlapping nature which will eliminate the missing of any hole during the detection process. For each region the reference node is selected randomly. Thus the energy required for detecting holes is reduced. Further a comparison of time consumed and the number of hole detected by both existing and proposed algorithm is also given [fig3,4]. The designed algorithm (MHDA) Modified coverage Hole Detection Algorithm is also implemented in real-time with a network consisting of three nodes.

IV. Simulation

Wireless sensor networks are the one where nodes are deployed randomly over the monitoring region such that some part of the network has suffcient coverage due to the presence of several redundant nodes, whereas other parts may have coverage holes due to absence of sensor. As soon as the network is formed, each node knows its location information and collects its one and two-hop neighbours' list. The sensing range (Rs) is equal to the communication range (Rc) and each node knows its location information via GPS or any location information system. Each node collects its two-hop neighbours' location information as soon as the deployment is over, i.e. each node knows the location of its neighbours within the range of 2 Rc .

A. Definitions

The important parameters that are to be considered in the algorithm are

Sensing range (R_S): Sensing range of a node is the circular disk of radius Rs, which is centered at its location. It is the sensing range of the sensor used.

Communication range(R_C): Communication range of a node is the circular disk of radius R_C, which is centered at its location. It is the antenna range of the communication device used in the node.

*Reference node (R_N)***:** A source node that initiates to execute the hole detection algorithm is called a reference node (R_N) It is to be noted that a reference node ûrst collects its neighbors information located within 2Rc and executes the hole detection algorithm.

*Neighbor***:** If A and B are any two nodes such that distance between them, i.e.(d_{AB}) d” R_C , then A and B are one-hop neighbors to each other. However, if R_C <d_{AB}d”2 R_C, A and B are two-hop neighbors to each other.

*Circumradius (R)***:** Radius of the circum circle formed by location of any three sensors as the vertices of a triangle is called circum radius R.

[1]Asso Prof, Sri Sai Ram Engineering College, Chennai, India

Circumcenter (Z): Center of the circum circle formed by location of any three sensors as the vertices of a triangle is called circumcenter [fig.1].

System framework: In our system A

model, it is assumed that there are multiple coverage holes in the monitoring region and the network is connected. Therefore, the one-hop and two-hop neighbors of a node must be connected with it through one and multi-hops, respectively.

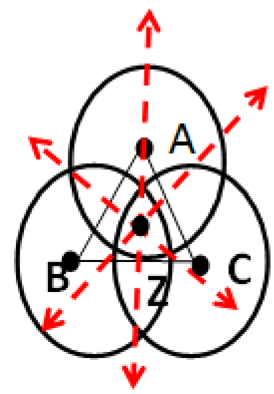

Fig.1 Circum radius (R) and circumcenter (Z)

For example, as shown in [Fig. 2], if A is considered as a reference node, it is connected with other nodes of the network with help of its one and two-hop neighbors though coverage hole exists in the network. In fact, B and D are one-hop neighbors of A. Hence, A is connected to C and E through its one- hop neighbors B and D, respectively.

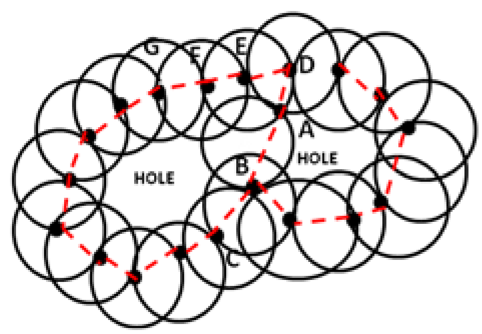

Fig.2 Connectivity with holes in the network

Besides, C, E, F and G are two- hop neighbors of A as they are within its 2Rc. Though, A is not connected with G and F through its one-hop neighbors B and D, it is connected with them through its two-hop neighbor E, which is connected to D. Hence, the whole network is connected though there are coverage holes in it.

B. Collection Of Neighbor Information

In this phase, a reference node is selected randomly from any part of the deployed region, which undergoes the neighbor discovery phase. The reference node broadcasts HELLO1 message that contains its location information. Upon receiving the hello message, a node calculates the distance d1 between the reference node and itself. If d_1d”Rc, the node sets itself as one-hop neighbor of the reference node X and unicasts its location information and ID to the reference node

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X. In the next step, each one-hop neighbors of the reference node X, broadcasts theHELLO2 message that contains the location information of the reference node X. Upon receiving the HELLO2 message, each receiver calculates its physical distance d_2 from the reference node X. If d_{2}d” 2Rc, the sensor sets itself as a two-hop neighbor of reference node Ultimately, reference node X records the location information and ID of each of its one and two-hop neighbors. This procedure is executed by each node of the network in a distributed manner by unicasting its location information and ID to the reference node.

C. Algorithm

In the algorithm discussed Rs refers to the sensing range. X is the Reference node (R_N) initiating the hole detection algorithm. N is the set of neighbors of X. (α ,β) is the Location of X. Nu refers to set of neighbors whose y-coordinate e” β.N_d is the set of neighbors whose y- coordinate < β. Area of the monitoring region is given as the input. Values to be found are Length of sides of triangle a, b& c, Circum radius R, Area of triangle “, Circum center Z, Angles of the triangle.

1. Phase I: Divide the entire network into16 clusters each having different size.
2. Select any node X randomly as R_N
3. Find 1 & 2 hop neighbors of X & assign to set N.
4. Select nodes of y-coordinate e”β from set N &assign to set Nu.
5. Arrange nodes of x-coordinate of Nu in ascending order & assign to a new set N_{UX}.
6. Select nodes of y-coordinate < β from set N and assign to set N_d.
7. Arrange nodes of x-coordinate of N_d in descending order & assign to a new set N_{DX}.

1. Phase 2: Select 1st 2 nodes of A_i & A_j of N_{UX}.
2. The x-coordinate of A_i must be less than A j.
3. Compute R & Z of triangle $\Delta X A_i A_j$
4. Check $\Delta X A_i A_j$ is acute or obtuse.
5. If $\Delta X A_i A_j$ is acute & Rd” Rs, no hole exists, else hole exists around $R_{NX.}$
6. If Δ X A_i A j is obtuse & Rd” Rs, no hole exists.
7. Else check if Z is covered by sensor.
8. If Z is covered no hole exists, else hole exists.
9. Update $N_{UX} < N_{UX}$ - {A_i}.
10. The phase 2 steps are repeated in loop with the overlapping cluster until N_{UX} is not equal to 1 for each node.

1. Phase 3: Choose 1st node Ai of N_{DX} & balance node A_j of N_{UX}.
2. Execute procedure from step 3 to step 8 of phase 2 for set N_{DX}
3. Update $d_{Nx} < N_{DX}$ - {Ai}.
4. Continue procedure until N_{DX} = null.

D. Analytical Proof

Each sensor forms a triangle either with one pair of its one-hop or two-hop neighbors or with one node from its one-hop and another node from its two-hop neighbors. As given in the hole detection algorithm, the presence or absence of the hole depends on the nature of the triangle. In order to justify the correctness of the algorithm analytically about ten lemmas are proposed [12]. These Lemmas are summarized in [Table I] .If acute triangle is formed by the reference node with 1 hop neighbors with the maximum acute angle being π/2 then there are no holes within 3 sensors.

Proof: The circumcentre will be located at most on one side of triangle & R<Rs. Common sensing range also exists. So circumcentre must be covered by any of 3 sensors.

E. Simulation Results

The simulation using mat Lab provides the distribution of nodes is an area and the presence of hole in the region based on the different lemmas provided in [Table I]

TABLE I. LEMMAS FOR HOLE DETECTION

Hop Neighbor			1	2	3
Acute Δ		$R=R_s$	No Hole	No Hole	No Hole
		$R>R_s$	-	Hole exist	Hole Exists
Obtuse Δ		$R=R_s$	No Hole	-	-
		$R>R_s$	Hole exist		
	Acute angle	$R=R_s$	-	No Hole	No Hole
		$R>R_s$		Hole exist	Hole Exists
	Obtuse angle	$R=R_s$		-	-
		$R>R_s$		Hole exist	Hole Exists

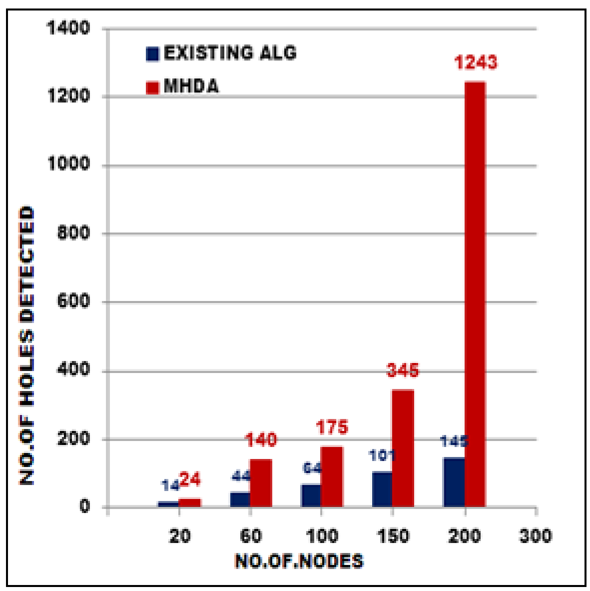

Fig.3. Comparison between the MHDA and the Existing Algorithm for Hole Detection

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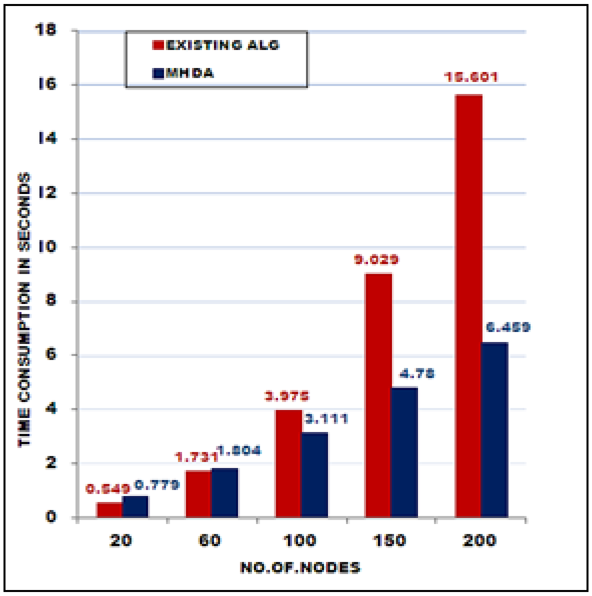

Fig.4. Comparison between the Time of Detection in MHDA and the Existing Algorithm

V. Real-Time Implementation

The hardware implementation consists of 3 motes. Any one mote is considered as the reference node. The reference node collects the location of the other two neighbors. The location of each mote is known using GPS. The neighbor locations are transmitted to reference node using Zigbee with the location information the reference mote executes the hole detection process. The GPS &Zigbee are interfaced to the mote using UART as shown in fig [5].To initiate Zigbee transmission AT commands are used. The GPS updates the position of each node for every finite interval of time. The hole detection algorithm is loaded into the microcontroller using KEIL software & is dumped in the microcontroller using FLASH NXP software. Thus the hole detection process is implemented & real-time results are obtained.

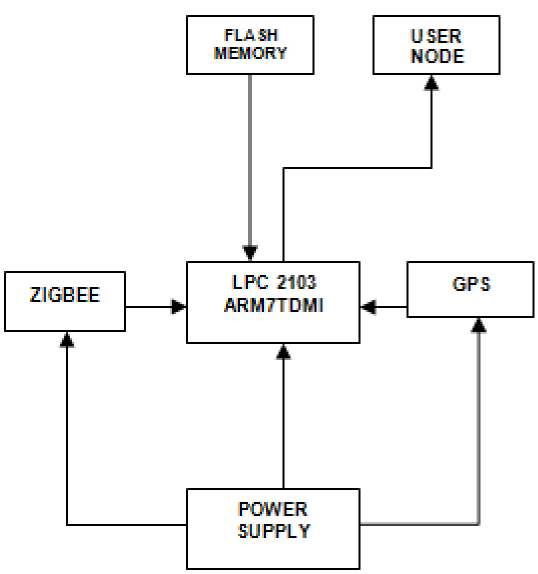

Fig.5. Block Diagram of a Node used in Real time Implementation

Each mote consists of GPS, Zigbee and LPC2103 ARM7TDMI Microcontroller. In GUI the coordinates for the 3 motes are obtained by connecting UART cable to the laptop. By varying the sensing range we can know whether hole exists or not.

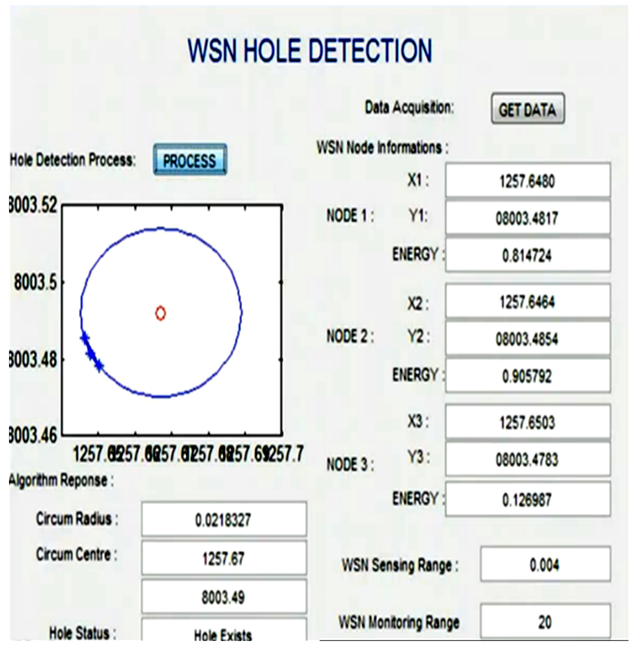

Fig.6.Output Window Of Real-Time Implementation Showing Hole Exists

V. Conclusion

The proposed system thus finds the existence of holes in the network using computational geometrical approach with less energy by considering the communication range R_c of each node equal to the sensing range R_s. The proposed protocol detects the coverage holes irrespective of any shape or size of the monitoring region [14]. Holes are detected taking into consideration the overlapping contours so that the chance of missing a hole is negligible leading to the reliable implementation of the proposed algorithm in any form of monitoring region and therefore could be more useful and beneficial as compared to the similar hole detection protocols. The hole detection ensures data reliability and efficient routing. The performance of the proposed system has been examined through simulations with variable number of nodes proving that the number of holes detected and the time taken for the same are better in MHDA than the existing algorithm especially when number of nodes deployed are more.

The hole detection algorithm can also be applied in the topological network in future where energy consumption can be decreased further. Appropriate clustering algorithm can be used to perform the best clustering with sensor heads initiating the algorithm in a cyclic or fixed patteren.A dedicated device can be constructed to monitor the existence of all types of holes throughout the entire lifetime of the wireless sensor network. The device should serve the purpose of both hole detection and hole healing making the communication between sensor nodes more efficient.

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